The evaluation of capital investment for improving the performance of aging equipment in Nuclear Power Plant

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1. Introduction

To improve the performance of aging equipments in Nuclear Power Plant, utilities have invested in capital facilities in large scale annually. In this regard, the Decision Making Tool is required in the feasibility analysis when the executives assess the effectiveness of capital investment regarding the safety, performance and economics of the equipment of a plant. The method developed is based on 'Analytic Hierarchy Process'. The tool is described herein, from selecting the indexes to the implementation of the simulation, and the result of evaluation is described.

2. Methods and Results

In this section, some of the techniques used to model the prioritization of capital investment are introduced. The model consists of ; the selection of investment evaluation index, building the hierarchy structure of evaluation, the comparison of relative importance, the benefit of estimating result from the investment, the method of ranking for prioritization, and the result of implementation.

2.1 The selection of the investment evaluation index

In the capital investment of nuclear power plants in operation, the index, which is criteria assessing relative importance index and monitoring facilities in the plant, drive equipment to achieve the objective of plant management. For the investment index assessing investment items requested, they are the safety, critical maintenance, reliability, power uprate and productivity. The safety required to meet regulatory commitments is a driver to improve the performance of the nuclear safety, personal safety and radiological safety in plant. The critical maintenance means that the aging equipment for electric power production is repaired and replaced. The reliability is to upgrade the performance and value of equipment in the plant. The power uprate that can increase the capacity of electric power generation replaces equipment. The productivity raises the efficiency of operation to shorten outage duration and reduce cost.

2.2 Building a hierarchy structures of the best decision

The evaluation index, which is used to realize the investment in the various functional areas of the plant in operation, is stratified. The top level is the goal of the evaluation. The 2nd level indicates the criteria of relative important index. 3rd level is the absolute evaluation index. The lowest indicates the variants of investment to improve the performance of plant. The index is a degree of contribution of each area respectively in the hierarchy structure.

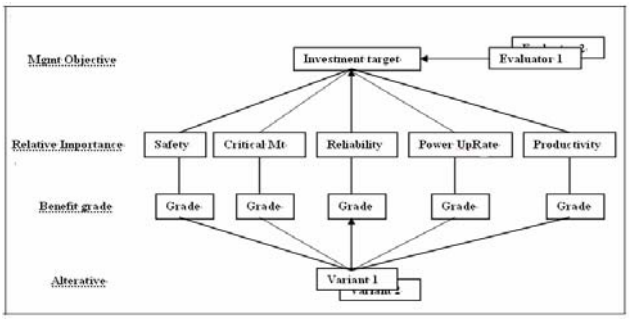

Figure 1 shows Hierarchy Structure as an evaluation model of capital investment in Nuclear Power Plant.

2.3 Calculation of the relative importance for the index in plant's investment target

2.3.1 Pair-wise comparison

A square matrix A is resulted from assessment of the relative importance for indexes in analytic hierarchy.

2.3.2 Calculation of eigenvalue and eigenvector

$$A \cdot \nu = \lambda \cdot \nu \quad \text{if and only if,} \quad \nu \neq 0 \qquad -(1)$$

$$(A - \lambda \cdot I) \cdot \nu = 0 \qquad -(2)$$

Eigenvalue λ and eigenvector ν become a solution to this equation. The solution, which cannot be equal to zero, to this homogeneous linear equation becomes an eigenvector against the eigenvalue λ. If the number of λ is substituted in the expression (2), the number of ν can be found. Eigenvectors are expressed as a percentage by normalizing them so as to make the sum one.

2.3.3 Verification of consistency for the evaluation

A maximum eigenvalue is selected to discriminate consistency for the result of evaluation.

$$Consistenc\,y.Rate(<01) = \frac{consistenc\,y\_index}{random\_index}$$

2.4 Deciding grade of benefit for the investment

Expected benefits resulting from the evaluation in investment item requested (alternative) are graded according to 5 criteria. In added as absolute score for the criteria, the grade is evaluated on the basis which is

presented with NPV of the economics or PSA of the safety.

Grade	Benefit (safety and economics)	
5	Reduction of 100 f/y-Rx, Increment of 200Mwon/y	
4	Reduction of 10 f/y-Rx, Increment of 20Mwon/y	
3	Reduction of 0 f/y-Rx, Increment of 0Mwon/y	
2	Reduction of -10 f/y-Rx, decrement of 20Mwon/y	
1	Reduction of 100 f/y-Rx, decrement of 200Mwon/y	

The fig -2, the 5 grad in absolute evaluation

2.5 Decision of prioritization in integrated evaluation

The prioritization resulted from integrated evaluation for investment variants is decided by total score as follows

Total Score = the rate of relative importance × absolute evaluation grade score

2.6 The implementation of decision maker in simulation

The investment prioritization for 15 investment requested items have been simulated by 10 evaluators who had worked in nuclear power plant.

2.6.1 Relative importance for the index

According to the assessment of relative importance for the index, the safety has the highest priority among evaluation indexes in the capital investment of aging equipment as Fig-3.

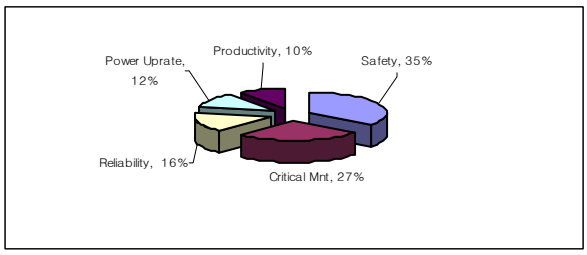

Fig 3- Relative importance

2.6.2 The grade of benefit for the investment

The evaluation is meant to improve economics of plant in investment prioritization. The trend of benefit estimated is slightly increasing in the economics.

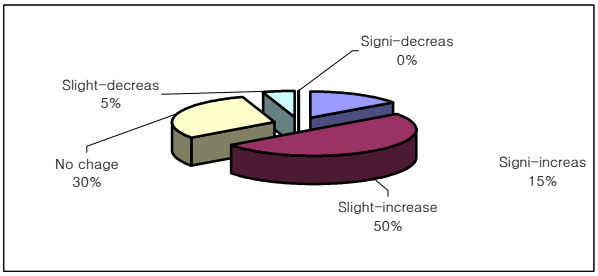

Fig 4- Grade of the benefit

2.6.3 The result of integrated assessment

For the priority of the capital investment, the result of simulation says that the safety improvement is more important than economics. The critical maintenance is continuously elevated in nuclear power plant.

Besides the Power Uprate, the productivity is set with the lowest priority.

2.6.4 The result of decision making tool

In a simulation assessing capital investment items requested, the decision making tool, which is judged upon rational and systematic support, provides a solution to improving the safety and economics in nuclear power plant.

3. Conclusion

It is not easy for the person, who is responsible for management of the equipment, to select and decide an investment items requested among complicated and various equipment in operated station. And also, the decision making of the capital investment in nuclear power plant is not judged with an economic measure. If the decision making tool, which adopted more rational decision making technique, is used in assessing capital investment, the objective of investment will become clear. The capital investment made on the basis of the importance of evaluation index will be objectified and achieved. As a result, the safety, reliability and economics efficiency of the plant will be improved.

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